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PHYSICS AND THE CONCEPT OF ENERGY:

A Study of Heisenberg's Philosophy

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ABSTRACT

PHYSICS AND THE CONCEPT OF ENERGY

By Elizabeth Sonnier

This thesis presents a twofold argument for the acceptance of an energeticist ontology based on Werner Heisenberg's philosophical works. The first argument claims that energy is a more appropriate unitary concept in physics than is the concept of matter. The second argument presents a phenomenological analysis of ordinary experience in terms of energy as measurement of interaction as opposed to a materialist analysis of ordinary experience. Energeticism as interactionism is shown to accord with ordinary experience whereas materialism does not. This proof leads to novel criteria of scientific coherence which have been lacking in philosophy of science. It also serves as a vindication of a realist philosophy of science.

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CHAPTER 1

Introduction

In his recent work entitled *The Scientific Image* Bas Van Fraassen remarks:

> Philosophy of science is not metaphysics—there may or may not be a deeper level of analysis on which . . . the real world is subjected to scrutiny and found to be—what? I leave to others the question whether we can consistently and coherently go further with such a line of thought. Philosophy of science can surely stay nearer the ground.[1]

In opposition to Van Fraassen's remarks above, this thesis proposes a philosophy of science which is a metaphysics.

Metaphysics here refers to the study of what the real world is like, of what existence is. The philosophy of science proposed herein is an attempt to validate a realist philosophy of science whereby concepts in science can indeed refer to the real world and give us knowledge of the world and of existence. At the outset, this proposal should not be misconstrued as a claim for the reality of all entities referred to by physics. Instead, arguments will be put forth to show that the scientific concepts of *particle* and *matter* do not refer to the real world, but the concept of *energy* does.

A materialist metaphysics has for the most part determined both the scientific and nonscientific view of reality over the past three hundred years. *Materialist metaphysics* is herein defined as a theory that what really exists are particles which are very small bits of solid stuff out of which the world is made through the conjoining, motions, and separations of these particles. Despite Van Fraassen's claim that science need not presume or entail metaphysics, the history of science and of

modern western culture shows a predominant belief in the existence of particles or matter. This belief was shared by the founding fathers of science, such as Newton and Galileo, and it has become part of the common culture shared by western peoples. Despite religious doctrine which gives materialism a minimal if not negligible role in its belief system, particle metaphysics has become somewhat a given to people who share a respect for science but are not experts in the field of physics. Moreover, many physicists still hold to some version of a particle ontology. There are no studies showing what percentage of physicists still believe that particles are real, but we have the testimony of eminent physicists such as Anton Zellinger who maintains that "Most physicists are very naive; most still believe in real waves or particles."[2]

Our inherited materialist ontology has caused us to presume a *dehiscence* between our ordinary experience of the world and scientific knowledge of the world.[3] As far back as the seventeenth century, scientific microscopic technology presumably revealed a previously hidden world of corpuscles which could not be viewed by the naked eye. These microscopic discoveries seemed to confirm the belief that the world as experienced through our sense organs could only reveal a superficial level of the true nature of the world, and that on a deeper level the world proved to be composed of atoms or corpuscles or particles. This materialist metaphysics gives us a picture of reality and our experience of reality which goes like this: Through our senses we experience material reality in the form of large material objects such as mountains, chairs, people's bodies, etc.; but with the aid of science we come to know that hidden in these material bodies is a deeper layer of smaller bodies

which we cannot see with our ordinary senses. By the nineteenth century we came to learn that hidden within these deeper layers of smaller bodies, still smaller, deeper layers of material bodies exist and are the fundamental deepest reality. Thus, since we could not see these particles with our crude sense organs, then our organs of sense were, at best, inaccurate means of knowing the world in its truest, deepest, reality; and a deeper knowledge of the true material or particle reality could only be achieved through experience gained from scientific data and with the aid of technology.

The deeper analysis which Van Fraassen speaks of is an example of the unwarranted separation between scientific data and what is taken to be ordinary experience. The notion of levels of knowledge or levels of experience such that one might speak of deeper levels of experience or a deeper knowledge as opposed to the superficial or lower levels of ordinary sense experience serves to perpetuate the myth that there can be no coherence or at least no indubitable correspondence between scientific theory and ordinary experience. There then arises the problem of how we can know that science is knowledge. What is viewed through the aid of a microscope must be, in the end, interpreted by our sense organs. If the results of this interpretation suggest to us that our unaided sense organs cannot accurately perceive the way the world really is then we cannot rely on our sensory interpretations of scientific data any more than we could rely on our unaided senses.

This problem of reconciling science and ordinary experience is further compounded by the revelations garnered from quantum mechanics, as shall be shown through a study of Werner Heisenberg's

evaluation of the findings of quantum theory. Using Heisenberg's application of an energeticist ontology to the findings of quantum theory and relativity theory, the concept of *energy* can be coherently and consistently applied to all of human experience: it can be applied to brute perception, experimental data in science, and it can moreover apply to the validation of criteria of coherence itself. One should not presume that such application need be in terms of deeper levels, rather, the task of metaphysics can be an analysis of the concepts of physics in terms of all facets of human experience and knowing. Thus we might say such analysis is broader rather than deeper.

CHAPTER 2

Heisenberg's Non-materialist Realism

Heisenberg became a prominent figure in physics in the mid-twenties when he played a major role in the formulation of matrix mechanics. His insights into quantum theory and his postulation of the uncertainty principle led him, as early as 1937, to the conclusion that the concept of *matter* was both scientifically and philosophically inadequate.

> The preference for one particular perceptible quality—the taking up of space as a quality of atoms—does however seem to show a lack of consistency. . . . In its essence, it is not a material particle in space and time but, in a way, only a symbol on whose introduction the laws of nature assume an especially simple form. Modern atomic theory is thus essentially different from that of antiquity in that it no longer allows any reinterpretation or elaboration to make it fit into a naive materialistic concept of the universe. For atoms are no longer material bodies in the proper sense of the word.[4]

The universe is not made of matter. Although the concept of *matter* has proven to be a useful tool by which scientists have formulated mathematical equations, Heisenberg believed that this does not mean that the term, *matter*, corresponds to actually existing material bodies. Heisenberg never once faltered in this firm conviction. However, philosophers err when they see such conviction as a statement of a non-realist philosophy:

> According to Heisenberg, there is no deep reality—nothing down there that's real in the same sense as the phenomenal facts are real. . . . Neorealists claim that the familiar objects that make up the everyday world are themselves made of ordinary objects, they believe, in short, that atoms are 'things'. This straightforward view of the world's real nature has been generally dismissed by establishment physicists as misguided and hopelessly naive.[5]

> Werner Heisenberg, for instance, considered this way of thinking as outmoded as the idea of a flat Earth: "The ontology of materialism rested upon the illusion that the kind of existence, the direct 'actuality' of the world around us, can be extrapolated into the atomic range. This extrapolation, however, is impossible. . . . Atoms are not things."[6]

In this passage we see the kind of error which is commonly made in regard to Heisenberg's early thought. It assumes that if one is not a materialist, then one must be a non-realist. At the outset one assumes that reality can only be defined in terms of things, atoms, or matter because one is assuming that there are no alternative concepts which might define reality. This shows how very deep-seated is our acceptance of a materialist ontology. But it is this very ontology which Heisenberg initially believed untrue. This does not necessarily mean that he believed science does not inform us of what he himself referred to as "a deep reality." In his early work he was concerned with discovering what message is sent to philosophy and science when we claim that *matter* or *atom* is an inadequate concept. He was rather perplexed by what this might mean. If the universe is not made of matter, if things are not solid and permanent, and if *thing* itself is a concept whose meaning must shift away from our view of the solidity of matter and the permanence of *thingness*, then how shall we communicate our findings? "The most common terms would need revision and there is no knowing how much of our language would remain." [7]

All of our Indo-European language—philosophical, scientific, and ordinary—is based on an object-centered vocabulary (as opposed to languages which are verb-centered or pictorial written languages). The articles and nouns of our language would lose their usual meaning if we

shift away from a thing and object-centered vocabulary. The often ambiguous meanings of words would no longer be merely ambiguous, they would be just plainly off the mark. What kind of words might we use to express our newfound truths about a nonmaterial reality? Moving ahead of ourselves to the energeticist philosophy later discussed, we might, for example, replace the word *chair* (a noun representing a fairly solid, permanent object within the materialist ontology) with *chairing formulation* or some such presently unusual word phrase.

Heisenberg was aware of this inadequacy of our present language as a tool for communicating the new perspective quantum physics was moving towards. He repeatedly focuses on the inadequacy of our language, both ordinary and philosophical, as a tool for explaining the non-materialist conclusions entailed in his philosophy. He was firm in maintaining that the concepts of *particle* and *wave* are meaningful only within a very limited, ambiguous, scientific framework; and that neither term is adequate in itself in defining or describing reality.[8]

This sounds very much like logical positivism which holds that lack of analogous carry-over into philosophical and ordinary language need not obviate the precision which mathematics, science, and logic engenders.[9] But whereas the logical positivists proposed that there is an inherent lack of precision in ordinary language which engenders false questions and category mistakes, Heisenberg believed that ordinary language was not inherently inadequate, but rather, some of our present language and current concepts present us with our problematic. For Heisenberg it was not the case that wave and particle were the best possible concepts we could use to describe the phenomena in question,

rather, they are the best possible terms in our present vocabulary. He believed that new concepts and new terminology play a significant role in the history and the future of science, and he also believed that part of the role of science is to give us new nonscientific and new philosophical concepts. His only concession to the logical positivists was that, try as he may, he could not foresee (in his earlier period) what such a new perspective or new concepts might be. So that whenever we find him sounding like a positivist, his statements are qualified by the inadequacies of *present* concepts, of our *present* framework, and our *present* language:

> Modern physics also shows that the relegation of a question to being a "false" problem is only possible and can only become fruitful on this condition it must create the freedom necessary for the establishment of the required abstract interconnections. In our approach to a description of nature we use concepts which lack precision in certain respects, though we naturally cannot appreciate that at the time. Yet finding these weaknesses will lead to new knowledge only if they can be used in a definite way for an appreciation of new kinds of interconnections. So long as this has not been done, we have no reliable criterion for asking whether a problem has or has not a meaning. We must rest content with treating all theses of physics even those formulated mathematically—merely as word images, since we cannot know the range of accuracy of the terms and concepts used.[10]

Here we have what seems a quintessential positivist view of science. Heisenberg maintains that we have no means of discerning whether or not certain problems have or have not a meaning. Statements like this have led many philosophers to believe that Heisenberg was a positivist, such as Arthur Fine who states that "most physicists who do shy away from realism are influenced more by the tradition in which they are schooled. . . . That tradition is the deeply

positivist legacy of Bohr and Heisenberg."[11] Fine here claims that Heisenberg has left a deeply positivist legacy. Such would seem to be the case, given that Heisenberg claims that concepts of physics should be treated merely as word images, but this claim is clearly qualified by Heisenberg: "However, once these new connections have been established we can penetrate into a new world of concepts qualitatively different from the old."[12]

This is where Heisenberg's view differs from the positivist view, and it is this strain which unifies his philosophy. Scientific concepts should be viewed as problematic only before new connections have been established which then bring about a new world of concepts. One cannot emphasize strongly enough the complexity of this view. He is trying to explicate the problems which his non-materialist metaphysics entails for a meaningful communication or understanding of that view. The billiard balls of atomic theory serve as a tool for getting us out of the billiard room. He doesn't see yet how he'll get out, but he is sure the billiard room is a stiflingly narrow place to be, and that there is a world outside that room which, once entered, will reveal the balls as phantoms. The trick, as he sees it, is to organize these balls into a configuration or pattern of interconnections such that they are revealed for what they are, merely phantoms, and in so doing we open up the room to the outside world.[13] This may sound like a wild leap of faith, but we can carry the analogy a bit further. The configuration we have just hit upon has opened up a window through which the most brilliant cloud has floated into the room, instantaneously disintegrating both a handful of billiards and a part of the wall. We are on the brink of getting out and we see the

usefulness of the balls as a tool for getting us out, yet we see that these tools are configurations and no more. This is the view of the early Heisenberg—the right configurations (theoretical interconnections) will lead us into newer, bigger, cleaner rooms (theories), we just cannot clearly discern those new rooms yet. But true to Heisenberg's realization of the inadequacy of our present language and perspective, this billiard room analogy cannot capture the momentous departure from materialism with which we are now faced, for in our analogy, the room, the cloud and the window all carry for us too much materialist metaphysical baggage. His difficulty in imagining what a non-materialist conceptual perspective might mean could only be alluded to, it could not be fully explicated, given the prevailing materialist ideology. For this reason, Heisenberg went to great pains to show that the particle/wave duality was not merely a convenient and useful, imprecise analogy. It was the only analogy to work with at the time. "One should simply wait for the development of the language which adjusts itself after some time to the new situation."[14] His quandary over the difficulty of understanding the conceptual implications of quantum physics should not be mistakenly viewed as an early positivist philosophy for such a mistake could amount to overlooking the unified evolution of his early rejection of materialism and his later more developed non-materialist metaphysics.[15]

In his later philosophical work he tries to understand the basis, significance and consequences of his rejection of materialism. He is deeply concerned with what *matter* has meant in the past and what it can and cannot mean for us now. He is no longer completely puzzled by

the question of where science might lead, for he has found some clues to a possible new conceptualization which may lead to new developments. However, he believed that in order to come to such new developments we must first understand the development of our present concepts. He tries to understand current theory in relation to the views of philosophers and physicists of the past, for he believed, as early as 1935, that:

> it is important for a deeper understanding of modern science, to find out to what extent present-day research can be treated as a consistent development throughout the centuries of human endeavour for an understanding of nature, and to assess carefully its balance of success and failures . . . (because) practically all of science has been achieved at the sacrifice of previously important formulations of questions and ideas.[16]

He is concerned with an understanding of the basis of atomic physics. It is not a question of merely digging deeper into the present meaning of the rejected concept, *matter*, but also of recognizing the historical basis of that concept so that we may discover what "previously important formulations of questions and ideas" were made which have led us to the quest for knowledge about atoms, and for scientific knowledge in general. By returning to the questions which concerned ancient philosophers he was able to reformulate some basic problems which we have mistakenly presumed were already solved or unsolvable.

Foremost of the questions he reformulated was the question of what is or might be the substance of which reality is composed. He came to this question by historically reconstructing the intellectual temper of pre-aristotelian times. This, of course, is a natural starting place, since it not only forms the basis of western philosophical thought concerning the nature of substance, but it also constitutes the origin of the concept

of the *atom*, and it is just this basis of atomic theory which he is trying to understand.

Those extant works and references which have come down to us from ancient Greece reveal a decided preoccupation with defining the substance of reality. Thales believed this substance was water, Heraclitus believed it was fire, Plato believed it was the forms, and Democritus believed it was atoms (to name but a few). Underlying these diverse theories is the presumption that reality can be defined in terms of some underlying, homogeneous indestructible constant or *substance.* According to Heisenberg, Democritus presumed that substance must be material, and thus our usual presumption that the underlying substance of reality is matter, but there are other formulations of substance which are akin to materialism, such as Thales' water, etc.[17] He examined these different views as they might be evaluated by modern physics. He saw many parallels between modern physics and Heraclitus' fire and Plato's forms, but he went to great lengths to show the indefensibility of Democritus' view of atoms as the substance of reality.[18]

Modern physics has taught us that atoms are not indestructible:

> Elementary particles can change into one another, and the characteristic of indestructibility no longer applies in the old sense, e.g. a collision between a neutron and a proton can produce a meson. This is a process characteristic in general for the collision of two elementary particles of high energy. . . . The particles thus created have a definite mass and other definite properties, some of them being well-known elementary particles.[19]

Matter can be both created and destroyed, and it thus fails to meet the criterion of indestructibility of substance. Furthermore, matter fails

to meet the criterion of one basic, homogeneous, indivisible physical constant:

> In considering three basic substances . . . electrons, protons, and neutrons—as the component parts of all matter, we have not altogether covered the program of atomic physics. If only these three elementary particles existed, we could rest satisfied in the belief that there are three fundamentally different sorts of matter which can no longer be transformed into one another or related to one another. But in reality there are yet other forms of manifestation of matter, the most important being radiation. . . . But beyond that, still other elementary particles have been found . . . the positive electron . . . (and) meson . . . there are many indications that further elementary particles still exist which have not yet been observed because they have an extremely short life.[20]

Science, therefore, shows us that we erroneously presumed the indivisibility of matter's elementary units. There are so may of these basic simples, that they go against what was taken to be the definition of matter as comprised of simple indivisible units.

Heisenberg's strongest argument for the rejection of matter as substance comes, however, in a different form. He shows us that matter can have none of the observable properties which we normally assume that *existents* must have, moreover, *matter* is totally devoid of any of its presumed properties:

> Atomic physics took as a starting point the apparently natural supposition that our knowledge of the atom will, with increasing accuracy of observation, perfect itself more and more. Though atoms represented the final indivisible 'brick' of matter, they nevertheless appeared to be miniature parts of ordinary matter. The atom, then, at least in our imagination, was endowed with all the macroscopic properties of matter. Only in the course of time was it recognized that the smallest . . . could not themselves possess the 'sense-properties' of matter if they were to explain these properties on a larger scale . . . if we say that a stronger movement of the atoms within differentiates a hot from a cold body, then an individual atom can be neither hot nor cold. Thus the atom was progressively divested of all its 'sense-properties'. The only properties which appeared for a

> long time to be retained were geometrical ones—the atom took up space and had a definite momentum. The development of modern atomic physics, however, has removed even these properties.[21]

Here we come upon the basis of Heisenberg's rejection of materialism. The "development of modern atomic physics" which he writes of as having "removed even these properties" was the Heisenberg uncertainty principle:

> True, with a comparatively moderate demand for accuracy, we can speak of the position and velocity of an electron: true also that compared with our daily experience, this accuracy is quite considerable. But measured by an atomic scale it is insufficient, and a law characteristic for this miniature world prevents us from determining position and velocity with the desired accuracy. Experiments can be done enabling us to determine, say, the position of a particle with great accuracy, but in the course of this measurement the particle has to be exposed to strong external influences which are responsible for a considerable uncertainty as to its velocity.[22]

Just as we can no longer attribute to matter the sensible qualities which it was supposed to embody, we can no longer attribute to it a definition accurately quantifiable in terms of both spatiality and momentum, and since these properties were the only properties which appeared to be retained, but have also been removed, we have thus eliminated the last vestige of the properties of matter as substance, and if matter is not a substance, then the whole materialist ontology becomes suspect. This is the view of the early Heisenberg, and far from being a non-realist perspective, realism is absolutely essential to asserting that materialism is wrong. If we maintain that science gives us a possibly useful picture, but that such a picture need not accord with the real world, then we cannot claim that some previous picture is erroneous and cannot accord with reality, for in order to make such a claim we would

need to establish that the evidence by which we rule out previous theories is somehow indicative of the real world as opposed to the inaccurate picture inherent in the previous theory.

Indeed, Heisenberg clearly states that his view is not a positivist view, but one which asserts that physics deals with what he calls "the actual":

> It should be noticed at this point that the Copenhagen interpretation is in no way positivistic. For, whereas positivism is based on the sensual perceptions of the observer as the elements of reality, the Copenhagen interpretation regards things and processes which are describable in terms of classical concepts, i.e., the actual, as the foundation of any physical interpretation.[23]

Here Heisenberg is maintaining that the Copenhagen interpretation is not one which is based solely on phenomena but which also presumes that concepts in physics refer to the real world. Rather than resort to the qualia of perceptions as the postivists do, Heisenberg maintained that the Copenhagen interpretation refers to the real or actual as the basis of physical interpretation. What then, might this actual be to which quantum theory refers? According to Heisenberg, we cannot define the actual in terms of atoms or particles:

> In the experiments about atomic events we have to do with things and facts, with phenomena that are just as real as any phenomena in daily life. But the atoms or the elementary particles themselves are not as real; they form a world of potentialities or possibilities rather than one of things or facts.[24]

In his claim that "atoms or the elementary particles themselves are not as real" we find his basic non-materialist views about the substance of reality. These insights are discernible in both his early and later writings, but in his later writings he goes on to question the viability of

any possible substantial constant: given that matter is not the substance of reality, can we find any other concept which could be such a substance? Heisenberg believes so: "Just as the Greeks had hoped, so we have found there is only one fundamental substance of which all reality consists. If we have to give this substance a name, we can only call it 'energy.'"[25]

He offers as proof of this claim:

> The elementary particles are certainly not eternal and indestructible units of matter, they can actually be transformed into each other. As a matter of fact, if two such particles, moving through space with a very high kinetic energy collide, then many new elementary particles may be created from the available energy and the old particles may have disappeared in the collision. Such events have been frequently observed and offer the best proof that all particles are made of the same substance: energy.[26]

In our quest for further understanding of matter and the atom, physics has rejected matter, or rather, physics has given us energy as matter, but what is the philosophical significance of such a conclusion? We have sought to understand the unitary indestructible constant of reality and we have found that this constant is energy, but we must recognize that the unity of energy is somewhat opposed to the kind of unity we presumed as a characteristic of matter:

> For our senses the world consists of an infinite variety of things and events, colors and sounds. But in order to understand it we have to introduce some kind of order, and order means to recognize what is equal, it means some sort of unity. From this springs the belief that there is one fundamental principle, and at the same time the difficulty to derive from it the infinite variety of things. . . . But when one carried the idea of fundamental unity to the extreme one came to that infinite and eternal undifferentiated Being which, whether material or not, cannot in itself explain the infinite variety of things. This leads to the antithesis of Being and Becoming and finally to the solution of Heraclitus, that the change itself is the fundamental principle. . . .

> Energy may be called the fundamental cause for all change in the world.[27]

The unifying principle of energy focuses on the reality of change and the differentiation of changing events in the world. As a unifying principle this focus on change is opposed to the focus on static and inert quantities characteristic of the concepts of *matter* and *particle* as unifying principles. Thus in this different focus a different kind of unity arises. We know from experience our own vitality, life, activity, and dynamism, and we see such active vitality all around us. Somewhere along the way western man has come to presume that inert matter underlies the illusory or mysterious vitality we experience. The energy scenario outlined by Heisenberg calls us to a new perspective wherein our own vitality, activity and dynamism are shared by all of nature as the fundamental unifying substance underlying all existence.

CHAPTER 3

History of Energeticist Philosophy

For the most part, the passages from Heisenberg's works which have been heretofore cited form the complete statement which he made in regard to his claim that energy is the substance of reality. Except for some discussion of Heraclitus and Aristotle, Heisenberg does not examine the history of the concept of energy, nor does he delineate his claim that energy is substance from the claims of energeticists.[28] But just as he saw fit to examine the history of materialist philosophy in order to understand how the term is or should be used now, so too should we examine the history of energeticist philosophy so that we might better understand the ontology which such a philosophy entails.[29]

Furthermore, just as a materialist proponent might claim that there are many different versions of what falls under the general heading of materialist philosophy, so too might we claim that there are many different philosophies which might be termed *energeticist philosophy*. An examination of these various versions of energeticism is especially significant since there seems to be a long-standing tension between various energeticist philosophies and various materialist philosophies. By studying these energeticist theories and their conflicts with materialist philosophies there is a good chance that we may come to understand the claim that energy is the substance of reality.[30]

Central to any definition of energeticism is the concept of *activity*. We can begin to delineate energeticism from other philosophies by noting that all energeticist philosophy maintains that reality is active and not inert or passive. This central belief harkens back to Aristotle and the

meaning of the English word *energy* which is derived from the Greek word *energia* which means *activity*. The energeticist philosophy proposed here also accepts the belief in a *physical* reality, which can be defined as a belief that what is subject to the laws of nature and is perceptible through the senses is real. This philosophy maintains that what is physical is active. Given this very general definition of energeticism as a belief in an active physical reality we can trace a history of such belief and at the same time we can distinguish this proposed energeticism from other philosophies.

Initially, energeticism is distinguishable from materialism in that materialism maintains that the fundamental substance of physical reality is matter and that matter in itself is inert but is subject to outside forces. This was the view of Newton:

> All things being consider'd, it seems probable to me, that God in the beginning form'd Matter in solid, massy, hard, impenetrable, movable Particles, of such Sizes and Figures, and with such other Properties, . . . and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in pieces.[31]

Newton here maintained that matter is made up of impenetrably hard, massy particles, and he went on to characterize the movability which these solid particles are capable of:

> The Vis inertia is a passive Principle by which Bodies persist in their Motion or Rest, receive Motion in proportion to the Force impressing it, and resist as much as they are resisted. By this Principle alone there never could have been any Motion in the World. Some other Principle was necessary for putting Bodies into Motion; and now they are in Motion, some other Principle is necessary for conserving the Motion.[32]

Newton claimed that massy movable particles (particles are here interpretable as primary bodies) are passively or inactively able to persist in and receive motion. The *Vis inertia* which he refers to is a principle of inactive force, and he states that an active force such as motion is not inherent within the particles or bodies, but that activity must be attributable to some source other than the particles themselves. Thus motion is not inherent within the particles, but acts upon them from outside. *Active forces* and the *matter* upon which those *forces* act are, according to Newton, separate yet interrelated concepts. With some variations, this interplay of the concepts of matter and force has been a mainstay of modern science, and indeed, as Einstein and Infeld noted, "Throughout two hundred years of scientific research force and matter were the underlying concepts in all endeavors to understand nature."[33]

But whereas Newton believed that primitive particles of matter were inherently inactive, real entities,[34] some seventeenth century theorists held a different view on the relationship between force and matter. Most notably, Leibniz maintained that:

> there are to be found in nature no corpuscles of extreme hardness, no fluids of greatest thinness, no universally diffused subtle matter, no ultimate elements such as some thinkers call primary and secondary . . . something must necessarily be assumed in bodies other than a uniform mass and its transportation.[35]

Here Leibniz called into question Newton's claim that matter is incomparably hard when he claimed that there are "no corpuscles of extreme hardness." Leibniz held that there are no corpuscles such that they cannot be further broken down, and we cannot reach a level of ultimate particles which could be called the basic constituents of

material substance. More significantly, Leibniz went on to tell us what must be assumed in bodies other than mass and movability:

> It can be concluded that there must be found in corporeal substance a primary entelechy or first recipient of activity, that is, a primitive force which, superadded to extension, or what is merely material, always acts indeed and yet is modified in various ways by the concourse of bodies, through a conatus or impetus. It is this substantial principle itself which is called the soul in living beings and substantial form in other beings, and inasmuch as it truly constitutes one substance with matter, or a unit in itself, it makes up what I call a monad, . . . For even though there are atoms of substance, namely, my monads, which lack parts, there are no atoms of mass or of minimum extension, or any last elements, since a continuum is not composed of points.[36]

and also:

> We have suggested elsewhere that there is something besides extension in corporeal things; indeed, that there is something prior to extension, namely, a natural force everywhere implanted by the author of nature—a force which does not consist merely in a simple faculty . . . but is provided besides with a striving or effort. . . . Indeed, it must constitute the inmost nature of the body, since it is the character of substance to act.[37]
>
> First of all, we must recognize that force is something absolutely real even in created substances but that space, time, and motion have something akin to a mental construction and are not true and real per se but only insofar as they involve the divine attributes of immensity, eternity, and activity or the force of created substances[38]

In these passages Leibniz gave singular importance to the concept of *active force* as being inherent in substance when he stated that this force "must constitute the inmost nature of the body." Furthermore, he claimed that "force is something absolutely real," and that space and motion are not real per se, but are only real to the extent that they involve the divine attribute of activity or the force of created substance. The distinction between force and extension which he referred to is not addressed to Newton, since Newton too believed extension is not wholly

definitive of substance. Rather, his emphasis on active force as definitive of substance differs from Newton's philosophy of hard massy substances and, contrary to Newton's claim that force is external to bodies, Leibniz asserted that force is an internal property of all substance. Indeed, he went so far as to impart the active nature of substance to matter itself.

> There is a world of creatures, living beings, animals, entelechies, souls, in the smallest particle of matter.
>
> Each part of matter can be thought of as a garden full of plants or as a pond full of fish. But each branch of the plant, each member of the animal, each drop of its humors, is such a garden or such a pond. . . .
>
> Thus there is nothing fallow, sterile, or dead in the universe.[39]

In this passage Leibniz evokes a vision of matter as vibrantly active, as teeming with liveliness. Despite the clarity of such an image, his views on substance, matter and force are quite complex. His philosophy centers around the concept of *substance as monads* rather than substance as matter or as force, and the Leibnizean concept of monads is rather complicated. He characterized the concept of *force* in substances as somewhat analogous to the concept of *soul* in living substance. He was adamant that one should not conclude from such analogy that substances must be intelligent, and he maintained that the concept of *active material substance* is only loosely analogous to the concept of *besouled agents*:

> I concluded nevertheless, that we must not mix up indifferently, or confuse, minds or rational souls with other forms or souls, for they are of a superior order and have incomparably more perfection than have the forms which are sunk in matter, which I believe are found everywhere.[40]

Thus monads are active primitive substances, but the entelechies which are inherent within these monads are somewhat akin to the

Aristotelian concept of *formal cause*. The entelechy is the power within each monad to manifest its unique interaction with all other monads, and as such each monad has within itself the whole program of the network of relationships of all substance as a whole. We can liken this entelechy to the genetic encoding of a DNA molecule, wherein the coding of future development is programmed beforehand. We are indeed lucky to have this analogy from modern science by which we may somewhat appreciate Leibniz's monadology, but as Leibniz himself maintained, the philosophy of monads and entelechies should not be seen as supremely significant in the physics of substantial force he is outlining:

> All the truths about corporeal things cannot be derived from logical and geometrical axioms alone, namely, those of great and small, whole and part, figure and situation, but there must be added those of cause and effect, action and passion, in order to give a reasonable account of the order of things. Whether we call this principle form, entelechy, or force does not matter provided that we remember that it can be explained intelligibly only through the concept of forces.[41]

In this passage he clearly stated that what is important is not to what we attribute the force of substance, but that force and activity are the only ways that the nature of substance can be intelligibly explained.

Thus his emphasis on *force* or activity as manifest in these monads is sufficient to warrant his philosophy of science to be classed under the general heading of energeticist philosophy, given our definition of energeticist philosophy as a belief that what is real is active, although there is some question as to the status of Leibnizean monads as being perceptible through the senses, which goes against our definition of energeticism as maintaining that what is real is perceptible to the senses. It is important to note, however, that although he did not equate monads

with perceptible experience, the role of force or action is, to him, the great bridge which allows us to cross from our ordinary experience to knowledge of substance:

> What then shall we add to extension to complete the concept of body? Certainly nothing which sense does not verify. Sense, namely, establishes three things at once: that we sense; that bodies are sensed; and that what is sensed is varied and composite, or extended. To the concept of extension or variety, therefore, is to be added that of action. A body is therefore an extended agent. It can be said that it is an extended substance, only if it be held that all substance acts, and all agents are substances.[42]

Again, we meet with a complex philosophy which is not easily explained. Leibniz maintained that our perception gives us strong knowledge of our own activity of experiencing, and our perceptions give us knowledge of the activity and changeability of bodies, and this knowledge through experience is not only prior to knowledge of the materiality of bodies, but it constitutes our knowledge of them, and furthermore, it constitutes their reality.

As we may note in these passages cited, Leibniz placed special emphasis on activity and he went as far as asserting that active force "must constitute the inmost nature of the body."[43] Thus Leibniz was an energeticist since his view can be classed with those scientific theories which stress a definition of reality in terms of activity. The concepts of *force* and *vis viva* as used by Leibniz form the basis of the modern concept of *kinetic energy*, and although one may question the equivalence of his use of these concepts with the modern use, his emphasis on active forces is indeed part of the proposed definition of energeticism. The question still remains whether Leibniz was a realist,

but, there is little doubt that the science he derives based on his monadology falls within the realm of energeticist theory:

> The concept of *forces* or *powers*, which the Germans call *Kraft* and the French *la force*, and for whose explanation I have set up a distinct science of *dynamics*, brings the strongest light to bear upon our understanding of the true concept of *substance*.[44]

Leibniz did not cautiously assert that the concept of force is equally as important a concept as is matter. It would be expected that Newton would have claimed that force is a very important concept in bringing to light a complete understanding of material substance, but we would not have presumed that it brings the strongest light, for impenetrable bodies are his focus. Leibniz, however, did maintain that the concept of force "brings the strongest light to bear upon our understanding of the true concept of *substance*."

Considering such distinctions in their views, the science of dynamics which Leibniz mentioned should not be confused with a philosophy which holds to Newtonian dynamics. Leibniz's philosophy should more accurately be called a philosophy of dynamism which we can define as a philosophical and/or scientific theory that explains the universe in terms of forces and their interplay, and we can distinguish this type of theory from that branch of Newtonian mechanics, known as dynamics, which studies forces and their relation primarily to the motion of bodies. Newtonian dynamics places special emphasis on impenetrable, inactive bodies (substances), whereas Leibniz's dynamism emphasizes inherent active forces in substances.

Thus at a time in history which was most crucial for the development of the materialist ontology which has come to be known as

Newtonian mechanics, Leibniz, a dissenting thinker of great intellectual stature, did not hold fast to the materialist philosophy. Instead, he argued that the presumed little bits of *matter stuff* were at best an approximate or relative reality which could only be properly understood in terms of active energetic forces. When we view through a microscope the vivacious *bits of stuff* which make up what we supposed were hard solid things, it requires little else than faith for us to presume that the truly solid things are actually these little bits of stuff. On the other hand, it takes little more than simple logical deduction to conclude that perhaps the little bits of stuff are themselves no more solid or impenetrable than what we supposed were hard solid things. Despite this very obvious implication Leibniz and only a few other thinkers have adamantly rejected materialism in favor of a more active view of reality. As we shall see, the reason for the prevalence of materialism over energeticism has been due, in large part, to the carry-over of the concept of substance in both materialist and energeticist ontologies, but there is also another reason. Energeticist philosophers have almost invariably been religious philosophers. These versions of energeticism do not equate all of reality with the physical, rather they also maintain a belief that nonphysical, mental, spiritual and/or subjective existence is also real but this dual reality of mental and physical is nonetheless wholly active for the energeticist. This is the view of religious philosophers such as Blondel, Whitehead, Teilhard De Chardin, and, in more recent times, Ivor Leclerc and Errol Harris.[45] This school of energeticist thought has come to be called *process philosophy*. Foremost of the process philosophers has been Whitehead who maintained that *process* refers, in

the end, to a subjective becoming.[46] The energeticist philosophy advocated by Heisenberg does not hold the same view of the concept of process. *Process* is important, in the physical sense, as equivalent to interaction over time, but there is no direct correlation with such physical processes and some nonphysical, subjective being such as conscious substance or God. The advocacy of energeticism which includes a relation to nonphysical reality undermines its claim to being a physical theory. Philipp Frank was correct in maintaining that concepts of science, used in terms of a spiritual or occult becoming is not at all equivalent to a physical scientific theory of reality.[47]

CHAPTER 4

Concepts of *Energy* and *Interactionism*

Heisenberg is one of a very few energeticists who do not appeal to nonphysical properties of energy. Moreover, he is virtually alone among scientists who are willing to disavow the concept of matter although, as the eminent historian of science, Max Jammer, has maintained:

> The history of physics shows clearly that the introduction of the concept of *force* led to a methodological unification of the conceptual scheme of science. . . .
> "Force," so to say, was the common denominator of all physical phenomena and seemed thereby to be a promising instrument to reduce all physical events to one fundamental law. . . . But more important, perhaps, is that the concept of force was instrumental in the construction of the concept of energy, a notion whose contribution to a unified conception of physical phenomena is unquestioned.[48]

Thus there is some recognition that the concepts of energy and force may be the most fruitful and important concepts in all of science. *Energy* is the concept which ties together any and all experimental and theoretical work in the physical sciences. The "one fundamental law" which Jammer refers to is probably an allusion to a possible grand unified theory in the form of a theory of the unified forces of nature which may yet prove to be the only final scientific solution to myriad problems still facing physical theory, such as the reconciliation of relativity and quantum theories.[49] Despite this overriding importance of the energy concept, there are problems which seem to necessitate the continued use of the concept of *matter* in physics. Quantum theory has shown us that events observed in subatomic physics have both wave and particle properties, and that neither tells the whole story about these events observed. The standard interpretation of this problem of dual

properties is that energy has material properties, and matter has energetic properties. It would seem that matter indeed can be viewed in terms of its fuzzy wave properties, akin to the wave properties of energy. On the other hand, energy is sometimes discrete, as de Broglie showed that the wave function collapses into a discrete quantity. Energy, with its property of being discrete, has properties characteristic of matter. Moreover, Einstein's relativity theory, in the form of, for example, his famous $E=mc^2$ equation, shows that matter and energy can be transformed, one into the other, so that not only is matter a form of energy but energy is also a form of matter. Given this general knowledge that energy and matter appear to be complementary concepts, why would Heisenberg feel the need to claim that energy is the substance of reality? Heelan maintains:

> As energy is the only common non-vanishing factor of every physical transmutation, Heisenberg postulated that it plays the part of a "primary matter" or "universal substance". This acts like a basic field capable of being informed by any one of a series of stationary states (particle states) described by mathematical operators. . . . The total energy is independent of whether it is realized concretely as an atomic system or, for example, as radiation or kinetic energy of motion. The total energy is rather the limit which specifies what variety of forms is possible.[50]

This claim is the best support offered for the uppermost significance of the concept of energy, and that matter is a form of energy. It is the energy concept which is the only non-vanishing physical invariant of every observed physical event: *energy* is the concept which ties together all knowledge in physics. Heelan goes on to dispute this claim to energy being a universal substance. He maintains that it is not the only physical invariant, although he does concede that it is the only

one which "may not vanish for a particular system". But this concession is taken too lightly by Heelan, for it is its property of being non-vanishing for all systems which makes the concept of energy so important. He goes on to note that charge is also a physical invariant property analogous to the role played by the concept of energy, but we need only remind him that charge is a property of electrical energy, and thus still refers back to a measurement of energy. However, Heelan goes on to offer a most important argument against Heisenberg's claim to energy as universal substance:

> In the second place, energy is not a simple quantity but a component of a four-vector, indicating its essential relativity to a frame of reference. The frame of reference is provided by a measuring instrument representing the physical milieu of the system in question. Energy seems rather to be a *condition of possibility* specified by the milieu and limiting what can take place in the milieu. . . .
>
> The role of energy in the "ladder" is not primarily to provide the "substance" out of which the systems in echelon are made, but rather as a condition of possibility specified by the milieu and limiting the kind of system or process permitted in this milieu.[51]

Heelan is correct in maintaining that energy is not a substance, but if we look at his very interesting definition of what energy is, we may better understand why we should more properly call the concept of energy a measurement of interaction. He maintains that "energy is not a simple quantity but a component of a four-vector." Heisenberg would concur that energy is not the measurement of a simple quantity, but reality itself is not as simple as the Newtonian scheme would have us believe. There are no simple, invariant, single substances, rather, science measures a complex reality. The concept of energy, far from being a substance, is a measurement of interactions. Heelan notes that

energy is measured in terms of its relationship to a frame of reference provided by the measuring apparatus and its milieu. The physical milieu is the field of possible interferences upon the system. These possible interferences are, just plainly, possible interactions upon the measuring apparatus which can interact with the system. Considered in terms only of the system under observation, divorced from the interference of the milieu of the apparatus, energy is the measurement of possible interactions within the system only. What this means is that energy is the measurement of possible activity with reference to all possible activity with which it interacts. Heisenberg himself can offer us an understanding of this when he describes how he sees the quantum problem:

> Therefore, the transition from the 'possible' to the 'actual' takes place during the act of observation. If we want to describe what happens in an atomic event, we have to realize that the word 'happens' can apply only to the observation, not to the state of affairs between two observations. It applies to the physical, not the psychical act of observation, and we may say that the transition from the 'possible' to the 'actual' takes place as soon as the interaction of the object with the measuring device, and thereby with the rest of the world, has come into play; it is not connected with the act of registration of the result by the mind of the observer.[52]

In this passage, some ambiguity arises. To begin with, Heisenberg refers to "an atomic event." We can take this to mean that atoms as little things undergo some process such as motion, or we can read this as indicative of a new way of speaking about phenomena called *atoms*. Atoms are not things in motion but are themselves events. This interpretation is warranted, given that Heisenberg has already proclaimed that the Newtonian model of little bits of solid stuff in motion is an inaccurate picture.[53] In terms of this new way of speaking the

whole passage takes on an interesting significance. "What happens in an atomic event" can only apply to the act of observation, and this act of observation is not to be misconstrued as what one might call a psychical or subjective act. The atomic event is a physical act. Moreover, this physical activity of observing is an interaction between the measuring device, the observer, and the rest of the world:

> The measuring device deserves the name only if it is in close contact with the rest of the world, if there is an interaction between the device and the observer.[54]

Again, we should remember that the object being observed is itself an event, and as an event it becomes actual only through its interactive connection with the rest of the world (through observation). The state of affairs between two observations has no scientific meaning because the concepts of atom, mass, particles and fields can only derive their actuality from an interaction. The atom becomes actual as an interaction, and this interaction is what is measured. The relatively stable and discrete energy states which we call *atoms* are measurable and definable as *atoms* only to the extent that the observer is able to physically interact with the atomic system, and this requires that the observed atomic system be an active system (for example, light must be emitted or absorbed). Energy, as Heelan claims, is the concept which ties together the act of observation, its interaction with the world, and the activity of what is being observed. Just as the Greek origin of the concept of energia denoted activity, the modern scientific concept of energy refers to the measurement of work or change of a physical system, but work or change by their very definition in quantum terms, must be interactive. Every isolated physical system interacts with its

milieu. The milieu of the system which the concept of energy serves to measure and the processes which energy sets limits upon are themselves interactions, they are the interactions of the event and its interaction with the world.

Energy is such that the differentiation in terms of mass, fields, and its other forms, is only a relative distinction, and that the work of science is to formulate the interconnected relations which occur. The concept of energy has this kind of global holistic application in the field of physics, not just because it is a useful mathematical symbol, but also because this symbol is the concept which refers to the reality of our and the world's interactive connection. It is the concept of connection because, in a very important sense, it refers to events under observation, the event of observing, and their interconnection: it refers to possible, present, and past interactive events.

At this point we must take issue with Heisenberg's claim that energy is the one substance of reality.[55] Here is the major flaw in Heisenberg's ontology, for in maintaining that energy is a substance, we move too loosely within the domain of classical concepts. As *substance* originally meant a standing under and has retained this connotation as the noumena which stand under the phenomena, it entails beforehand a materialist ontology, or at least it fails to capture the significance of an ontology in which energy is reality, for energy does not <u>stand</u>, energy is not static. Energy as unified reality takes various forms, some of which can be said to stand, but we would not claim that, for example, thermal energy <u>stands</u>. If we equate reality with energy we would more accurately say that energy is not a substance, since we at least presently

equate substance with matter and *thingness*. Instead we must recognize that there is no such reality as substance. Nor should we claim that only *that* which acts is real. Rather, activity is real, and only to the extent that the *that* which acts is in turn recognized as an activity, can we say something acts: the something which acts is itself just a differentiated style of acting. Nor should we properly call *energy* an *entity*, indeed, if we examine what might be meant by *energy as entity* we see both the fundamental influence that the concept of matter has had in shaping our way of thinking about reality, and at the same time we can go very far towards elucidating the claim that reality is energy.

When we speak of an *entity* or *entities*, we are presumably referring to beings or existents. Such supposed reference entails a view of reality whereby we distinguish beings as agents or spiritual or mental substance from mere existents, such as composite material objects, or the basic constituents of which those objects are composed. The term *entity* harkens back to medieval and ancient views of reality wherein existing is linked to the notion of a discrete substance, or to a compound substance composed of discrete substances. For example, Descartes believed in mental substance and physical substance.[56] Under this view, one could refer to a human entity as a combination of mental and material substances. *Entity* refers to some object which we can physically or figuratively point to as existing. Energy, on the other hand, cannot be pointed to in this way, but is a holistic totality out of which we can distinguish various forms. We would not say that here we have an *entity of energy*, but here we have a *form of energy*. For example, we

would not speak of thermal energy as an *entity* for it is not a thing and it is not an object.

Furthermore, forms of energy, even under precise measurement, are not perfectly discrete quantities but are measurements of activity over a period of time. We have learned from quantum physics that even discrete forms of energy (energy in the form of particles) must have fuzzy boundaries with respect to space, time, and the system of which they are a part. The label of *entity* in reference to such quanta applies only if one recognizes that this concept refers to an event which can be measured only if it is abstracted from its relationship with other events with which it interacts.

Diverging somewhat from the view of Heisenberg, if we recognize that what physics quantifies and qualifies in its measurement and study of energy, force, and momentum is nothing more nor less than activity, and that reality as energy refers quite simply to interactions, and that what we take to be entities or substances are forms of interaction, then we have a definition, or description, or view of reality which defies the kind of substantialist label Heisenberg sought fit to use. An activity is not a substance, and what physics measures are activities and their interactions with other activities. The *substance* label is only a convenient shorthand which serves to allow for measurement of these different interactions. This criticism of Heisenberg is by no means a total refutation of his ontology, instead it might be deemed a clarification or augmentation of his view. Heisenberg too speaks of forms of energy just as the theory that energy is activity would emphasize forms of activity.

This revision of Heisenberg's energy ontology also differs from the emphasis he places on the Aristotelian potentiality/actuality distinction which he sees as indicative of probabilities and uncertainty relations of quantum theory. According to Heisenberg:

> we have here actually the final proof for the unity of matter. All the elementary particles are made of the same substance, which we may call energy or universal matter; they are just different forms in which matter can appear.
>
> If we compare this definition of substance with the Aristotelian concepts of matter and form, we can say that the *matter* of Aristotle, which is mere *potentia*, should be compared to our concept of energy which gets into *actuality* by means of the form, when the elementary particle is created.
>
> Modern physics is of course not satisfied with only qualitative description of the fundamental structure of matter; it must try on the basis of careful experimental investigations to get a mathematical formulation of those natural laws that determine the *forms* of matter, the elementary particles and their forces. A clear distinction between matter and force can no longer be made in this part of physics, since each elementary particle not only is producing some forces and is acted upon by forces, but it is at the same time representing a certain field of force. The quantum-theoretical dualism of waves and particles makes the same entity appear as matter and as force.[57]

What would seem to be Heisenberg's main focus in this passage when he claims that, "the 'matter' of Aristotle, which is mere 'potentia,' should be compared to our concept of energy" is that forces are potentialities which become actual when the elementary particle is created. Forces such as repulsion and attraction are only possible forms by which the particles may come to be and pass away. For example, a particle interacting with another particle may result in the annihilation of both of those particles and the creation of wholly different particles. An electron interacting with a positron can result in the creation of two photons, and two photons can change into an electron-positron pair.

With energy as potentia, as Heisenberg has defined it in this passage, the exchanges of energy and the forces of particles acting upon each other and the force of fields are thus all merely potential realities which become fully real only through the act which takes place and which causes the new particles, which are the actual, to appear. If forces and energy are only potential and the particle is the actual, then the substance, the so-called underlying reality, would seem to be the particle (the material) all over again. If, as he claims, the materialist ontology is wrong and the *substance* of reality is energy, then, given this passage, the substance of reality would appear to be neither real nor actual, but merely potential, so that what is real is not actually so. If instead we follow through completely with his claim that energy is substance, the delineation of the qualitative description of the structures of *particles* would need to be phrased in such a way that particulate energy is no more real than other forms of energy. We might instead say that the qualitative and quantitative description of forces in terms of the forms, symmetries, broken symmetries, and exchanges of energies are in themselves a complete description of reality. Here the shapes registered by detection instruments, and misnamed particles, can be seen as parts of a total space-time configuration, space and time both being part of the measurement of forms. In other words, the shape we see is a form in both the geometrical sense of a *form as a shape*, and in the qualitative sense of *forms as kinds of energy*, as different styles of interacting. Schrodinger concurs with the view that geometrical forms are all we know of matter:

> Let us now return to our ultimate particles and to small organizations of particles as atoms or small molecules. The 'old' idea about them was that their individuality was based on the identity of matter in them. This seems to be a gratuitous and almost mystical addition that is in sharp contrast to what we have just found to constitute the individuality of macroscopic bodies, which is quite independent of such a crude materialistic hypothesis and does not need its support. The new idea is that what is permanent in these ultimate particles or small aggregates is their shape and organization. The habit of everyday language deceives us and seems to require, whenever we hear the word "shape" or "form" pronounced, that it must be the shape or form of something, that a material substratum is required to take on a shape. . . . But when you come to the ultimate particles constituting matter, there seems to be no point in thinking of them again as consisting of some material. They are, as it were, pure shape, nothing but shape; what turns up again and again in successive observations is this shape, not an individual speck of material.[58]

In this view, the distinction between potentiality and actuality need not equate actuality with particles, and potentiality with energy, rather, energy is the qualitative and quantitative unity, real in the sense of the total network of forms of energy, fields of force, and the equations which are formulated in terms of these concepts. In this sense potentiality is captured as constructive interrelating of the elements within the total network, whereas actuality is then not properly energy, but activity, or better yet, interactivity. The claim that energy is an abstract mathematical concept without real content is only meaningful to the extent that one can claim that interactivity can never be viewed, really, as a totality of interactions, but that all we can know or all that is real is individual acts, for the concept of energy merely mirrors a unified system of diverse forms of interaction.

Although Heisenberg never equated energy with interactions as such we find that in his later years he was preoccupied with formulating

laws which would place energy as the central concept of a unified system of diverse forms of interactions. At least, this interactionist language is the way Weizsacker discusses Heisenberg's later work, and Weizsacker and Heisenberg were the most intimate of colleagues:

> What we refer to empirically as an isolated particle is in reality already the result of its interaction with the permanently co-present environment.
>
> These considerations suggest that we should on principle regard the properties of "isolated" particles as the results of interaction. The only decisive attempt made in this direction has been Heisenberg's nonlinear spinor theory. . . . At first, only one elementary field is given, its interaction being an interaction with itself. Thus the nonlinear character of all interaction problems is already given in the basic equation.[59]

This passage would seem to suggest that Heisenberg held the concept of interaction to be the most probable basis for an explanation of particles. The nonlinear spinor theory he proposed places ultimate significance on the concept of interaction in terms of the interaction of fields of interaction. Also, Heisenberg maintained that the formulation of new entities to explain observed phenomena is often misguided, and that what should concern us are the processes involved, and an explanation of these processes, and not the postulation of new entities.[60]

CHAPTER 5

Energeticist Ontology and Criteria of Knowledge

The re-evaluation of Heisenberg's energeticism presented here is one which claims that the concept of energy refers to the measurement of interactive events, and that interactive events are all there is in reality, and that, since activities are not substances, then substance is a concept which cannot accurately define reality. This revised energeticism can shed new light on the debate over the extent to which science can indeed give us knowledge of the natural world, and, moreover, it may shed new light on criteria of knowledge in science, and the relationship between scientific knowledge and our everyday experience of the world.

First, we must assess the distinction between the kind of analysis of experience which is implied by materialism, and the kind of analysis of experience made possible through an energeticist interactionism. Then we shall assess this distinction through a phenomenological analysis of our ordinary experience. The results of this phenomenological analysis will uncover a usually overlooked criterion of scientific knowledge which may be at least a partial vindication of a realist philosophy of science.

It will be important to keep in mind that the justification for the phenomenological analysis presented here is that the ordinary use of the term *energy* and its implication of active force and interactivity parallels with a phenomenological analysis of experience. The basic tenet here is that the scientific concept, *matter*, does not accord with our ordinary experience of the world, and that the concept of *energy*, divorced from its ordinary use in terms of energy as substance, does accord with our ordinary experience of the world.

Werner Heisenberg maintained that the concept of energy, and not that of matter, was a scientific term which referred to the *substance* of reality.[61] However, we can go one step further to maintain that the importance given to the concept of *matter* in both science and ordinary language has been responsible for the formulation of problems about man's knowledge of the world which do not arise if the energy concept is granted the same degree of importance which the concept *matter* has so long had. The claim that scientific uses of a term cannot be or should not be extrapolated from their scientific context and applied to nonscientific, ordinary experience is based on the presumption that there is no such correlation But in fact, our ordinary uses of these terms are derived from their scientific uses, and vice versa. Merleau-Ponty was to a large extent correct in maintaining that:

> The whole universe of science is built upon the world as directly experienced, and if we want to subject science itself to rigorous scrutiny and arrive at a precise assessment of its meaning and scope, we must begin by awakening the basic experience of the world of which science is the second-order expression.[62]

Merleau-Ponty is correct in claiming that our basic experience of the world can offer an assessment of science. But he goes on to claim that science can never offer the kind of significance that is entailed in the being of the world that we experience because science is an explanation.[63] But if the view science gives us removes from its explanation the non-phenomenological substances and occult entities which have so long been its central concepts, then perhaps it can keep as its focus the vitality and active context which is crucial to human experience. Thus, if science itself undercuts the kind of coloring of

experience which materialism engendered through its emphasis on *matter objects*, etc., it may prove to be an explanation of being which reconnects us to the world we experience. If we follow Merleau-Ponty's suggestion and assess certain concepts of science in light of their analogy to our actual experience, to the kind of model of experiencing the world which is implied by scientific explanations of the world, we can come to see the connection between scientific concepts and our everyday experience. In this re-evaluation no analysis of mathematical formulations will be given, nor will various formulations of theory construction be evaluated. Furthermore, the analysis of the concept of energy as used in its scientific sense will be used only to show the different explanations of perception which arise given energeticist and materialist explanations of how one *body* is influenced by another. It is important to realize that in maintaining the analogy between the scientific concept of *energy* and *energy as interaction* in the realm of ordinary experience, we are not here attempting to validate any nonscientific beliefs or concepts, such as minds or spirits or ethers, etc. Such attempts are abstractions from science which cannot be justified, but the analogy between our phenomenological experience in terms of interaction and measurements of interaction in the field of physics is quite apropos, since from the outset our phenomenological experience is our only inroad into the experiences which comprise the data of physics.

Since the formulation of energeticist theory at the turn of the century, its critics, such as Ernst Cassirer, have maintained that energy is at least as abstract a concept as matter, and that energy does not reflect our everyday experience of the world.[64] Heisenberg seems to

have shared the view that energy does not reflect our everyday experience, for he maintained that the concepts of modern physics reveal a deeper level of reality than is given in everyday experience:

> Our senses rank only as more or less imperfect aids enabling us to acquire knowledge about the objective world. It is only natural and consistent for the physicist to try and improve on the senses through artificial means of observation until we penetrate to the most remote fields of objective reality which are entirely beyond the range of our immediate perception.[65]

In this passage Heisenberg seems to be referring to Planck's constant which tells us that interactions below the threshold of a certain distance take on different characteristics. Thus Heisenberg notes that at distances smaller than this limit, our ordinary experience does not apply. One might assume that since energy is one of the concepts of modern physics, it must be reflecting a deeper level of reality than can be derived from ordinary experience. However, findings at the level of Planck's constant do indeed interact with so-called more superficial levels, and the compartmentalization of reality or experience into levels is at least an awkward approach which remains problematic because the indirect experience of the deeper Planck level must rely on the superficial levels for corroboration of findings. Significantly, Heisenberg also maintained:

> The experiments of physics and their results can be described in the language of daily life. . . . Difficulties arise only in the attempt to classify and synthesize the results, to establish the relation of cause and effect between them—in short, to construct a theory. This synthetic process has been applied not only to the results of scientific experiment, but, in the course of ages, also to the simplest experiences of daily life, and in this way all concepts have been formed. In the process, the solid ground of experimental proof has often been forsaken, and generalizations have been accepted uncritically, until finally contradictions have become apparent. In order to avoid these contradictions, it seems necessary to demand that no concept enter a theory which

> has not been experimentally verified at least to the same degree as the experiments to be explained by the theory. Unfortunately it is quite impossible to fulfill this requirement, since the commonest ideas and words would often be excluded. To avoid these insurmountable difficulties it is found advisable to introduce a great wealth of concepts into a physical theory, without attempting to justify them rigorously, and then to allow experiment to decide at what points a revision is necessary.[66]

In this passage Heisenberg shows an analogy between science and daily life. He maintains that science constructs generalized theories which are not always correct, but that close attention to the results of experiment can tell us where theories should be revised. But just as experiments allow us to pay close attention to the events we observe so that we might see past erroneous scientific generalizations by which we interpret these observations, so too can close attention to experiences of daily life allow us to see past erroneous nonscientific generalizations by which we interpret our ordinary experience. Science need not be deemed a deeper or more true picture of reality than can be derived from ordinary experience, but rather, close attention to daily experience and what our daily experience tells us can also point out problems in the concepts we use to interpret our experiences. Heisenberg is correct in noting that our concepts can distort what our basic experience can tell us. He is also correct in noting the historicity of these everyday concepts when he claims that "This synthetic process has been applied not only to the results of scientific experiment, but, in the course of ages, also to the simplest experiences of daily life, and in this way all concepts have been formed." The synthetic processes by which we classify experiments and our everyday experiences have their historical basis throughout the course of history.

Part of the project undertaken by phenomenologists has been the careful study of our experience in an attempt to overcome the historically determined distortions which we have superimposed on our experience through our previous acceptance of generalizations about these experiences. The concepts of *matter*, *thing* and *object/subject* are just such conceptual generalizations which are not entailed in our phenomenological knowledge. They are concepts which we have inherited from thinkers of the past who sought to explain experience in a systematic form, but careful attention to everyday experience can reveal problems inherent in these systems.

If we maintain that experiments in the subatomic realm do not accord with our everyday experience, we may be erroneously presuming that the concepts of *object* or *thing* are inherent in our experience of phenomena, but this is not so. Our everyday experience is as revealing as is science, it seems not to be so because we have for a very long time used just the very concepts which are now suspect in science as a way of generalizing about our experience. Once the matter ontology is rejected and the reality of *things* which we perceive are viewed in terms of activity then our everyday senses may not be so very far removed from what Heisenberg calls *objective knowledge*, for it is a mistake to presume that we can separate our beliefs about existence (our ontology) from our beliefs about how or what we experience, since our beliefs about how we experience are to a large extent determined by what it is we believe is experienced. The phenomenological analysis to be given here is the study of our experience as it is before we add on layers of cultural

coping, and the materialist ontology and interpretation of experience is just such cultural layering superimposed on our brute experience.

Since Descartes western philosophy has been an arduous quest for indubitable certainty. How can we be certain that our perceptions of the world are a true picture of reality? No matter how we organize, categorize, systematize, and analyze our experiences, we can never be certain that such systematization does not distort our experiences, and we can never be certain that our perceptions are not self-induced. Many philosophers puzzle over these problems, but inherent in these puzzles is the presumption that the *self* who perceives is significantly distinguishable from its perceptions, and furthermore, such quandaries must presume that perceptions are kinds of *phenomena* which are distinguishable from the *noumena* which cause them. Such distinctions are essential to a materialist ontology, since the particles which make up the brain (if the self is definable in terms of the brain) are not the same as the qualities which the brain perceives, and since the qualities which are supposed to inhere or be caused by the particles are not the same as the particles themselves. We have inherited an almost unconscious, dualist, materialist metaphysics which entails a *dehiscence* between the world and the self, and from such a basis we can never arrive at a firm ground for believing that any experience of the world, not even brute perception, can lead to knowledge of the world. Indeed, such a basis does seem to be the picture science gives us of perception. The light waves which travel to the retina are not the same phenomena as the particles inherent in the substance off of which the light waves bounce,

etc. With energy as activity the composite forms such as chairs or molecules are distinguishable from less composite forms such as atoms in terms of their styles of interacting. The form of energy we call *atoms* interacts with other like forms to form molecules whose active form is characterized as an interaction of other forms.

If matter is no more than interactive forms of energy, and mind is no more than an interactive way of doing, and if sense qualia are just ways of interacting, then the claim that energy as activity is an abstraction which does not mirror our experience loses much of its force. If we rethink the scientific description of experience, removing our presumption of particles as given, then we do not have light waves bouncing off of particles, but light waves interacting with forms of energy which we call *particles*, and these light waves interact with the energies which are our retinae, which interact with brain waves, etc. From this perspective, the *thing* we see is not so clearly distinguishable from the light which reaches our eyes. Rather, these various *waves* are forms of energy which, in interacting with each other, blend together as composite, holistic interacts, and thus the act of perception itself is as *substantial* and immediate as less composite forms of energy (if we can speak of non-composite forms of energy), and our eyes and our brains are interactive forms themselves. What I experience is nothing more nor less than the energetic vibrancy, both of myself and of the world I live through and with. Energy in this sense is the experience of power, strength, liveliness, forcefulness and volubility that characterizes every second of my life, every quiet moment, and surely every active moment.

The table before me is not a solid, inert object. It is a vibrant, energetic activity. If we examine closely our phenomenological experience we find that what I feel as the solidity of the table is its coolness and smoothness energetically touching me as I touch it—the table touching me, coming to act with me as I touch it. The coolness and smoothness I feel in my fingers becomes part of the terrain of my fingers themselves. What I know of the table is at the same time what I know of myself, and the disconnection of my experiencing the table from the table itself is not part of my immediate experience.

One cannot doubt that this description sounds alien to our way of reflecting on our tactile experience. The crucial point is that our way of reflecting on our tactile experience is too often framed by the concepts which we inherit from our cultural ideology, in this case, the material ontology which is taught to us at a very early age. To one who has never believed in the matter ontology, the energetic description seems not only closer to a brute phenomenological description of experience than does the materialist, mechanistic description, but it also seems the only good description. If one grants no presumed materiality to *tableness*, one divests it of its non-phenomenological traits and it becomes a brute apprehension whose sensory qualities stand on their own as what one knows of the being of the table through one's interactive taking-up of the table as a part of one's life activity of experiencing. As early as 1923 Ernst Cassirer offers a similar analysis of the energeticist ontology:

> The *atom* and *matter*, which constitute the real type of objective reality for the older natural science, are reduced to mere abstractions through the closer analysis of the data and conditions of our knowledge. They are conceptual limits, to which we attach our impressions, but they can

> never be compared in real meaning with the immediate sensation itself. In energy, we grasp the real because it is the effective. Here no mere symbol comes between us and the physical thing; here we are no longer in the realm of mere thought, but in the realm of being. And in order to grasp this ultimate being, we need no circuitous route through complicated mathematical hypotheses, since it is directly revealed unsought in perception itself. . . . The object ***is*** what it appears to be: a sum of actual and possible ways of acting.[67]

Cassirer here maintains that the concept of energy, in that it denotes the effective, (one might say the *active*) in our experience, entails more than a mere symbol and relates to being itself. The object of experience is then no more nor less than what it appears to be. It is the totality of ways of acting. We are then no longer plagued by the problem of defining the constituent elements of reality which our symbols are supposed to refer to. Rather, energy refers to the variety of actual and active changes which are our experiences themselves. Furthermore, unlike matter which refers to discrete yet selfsame entities, we do not have to try to imagine a unitary indivisible quantity of energy, since energy is not quantified in the same way that atoms are. Again, as Cassirer claims, it is the sum (the unitary basis) of actual and possible ways of acting (of measured quantifications of the world of interactions).

Cassirer goes on, however, to offer the traditional argument put forth against energeticism. Most basically the argument states that just as we could not claim that particles actually reflect what we experience, so, neither, could energy. Matter is not blue, it does not have any of the qualities by which we know reality, such as the colors we sense, and indeed, we do not experience matter in itself. Likewise, it is maintained,

we do not experience energy, energy is not colored, it has none of the qualities by which we experience reality:

> The notion that "energies" can be seen or heard is obviously no less naive than the notion that the "matter" of theoretical physics can be directly touched and grasped with the hands. What is given us are qualitative differences of sensation: of warm and cold, light and dark, sweet and bitter, but not numerical differences of quantities of work.[68]

Cassirer here claims that energy is as much an abstraction as is matter. However, if we examine closely such remarks about perception and energy we can see the materialist assumptions which are made within his argument. To begin with, the notion that energies can be sensed equates energy with the kind of substantial *thingness* by which we characterize matter, as though energy could be doled out as discrete quantities on which qualities are supposed to stand, as though energy should be likened to a piece of cloth upon which dye is poured. By supposing that this kind of characterization is required if experience is to mirror our ontology, we presume that the materialist connection between experience and reality is the only valid one.

Cassirer's claim seems in line with this view, and it also points directly to an evaluation of experience wherein perception is given the kind of status that particles have, in other words, it is presumed that experience is analogous to discrete sense qualities or sense data (little bits of sense stuff). We might even call them sense particles, as we might say that Cassirer's reference to sensing is like seeing a blue sense particle (a sense quale). But Cassirer is wrong in presuming that perception or experience is discrete (or at least that we can judge the correspondence of our theories with our ordinary experience in terms of

such discrete qualia), and that we can somehow dissect experience up into packets of qualia such as lightness and darkness, warm and cold, without attention to the total panorama of experience which forms both the basis and the goal of perception. This version of experience rules out beforehand the possibility that experience is a process or an energetic interaction wherein discrete sense data, (the *red-dot-now* scenario) is not an accurate account of experience. As a process, sensation of lightness or darkness, for example, is only part of a total process of perceiving, and this total process is the truly brute perceiving we experience without qualification. When we call attention to the sensing of various degrees of lightness or darkness as a way of assessing what we can or cannot know from our ordinary experience, we are laying claim to a special status for these sense qualities assignable in terms of parts of perception that in no way can merit such status. If sensing is a more complicated process, then its various aspects point to a more full-bodied total experience which might very well demand an interactive energeticism as its sole explanation—seeing is an energetic holistic process, and we sense it as such. We need not seek some distinctive feature of experiencing (like sensing warmth or light) by which we might judge the correspondence of that feature with the proposed real activity: experience itself is activity both in its singled-out features and in its overall reality. We never feel warmth alone, but always warmth in relation to a total system of interconnecting relations, which as a whole form a distinctive style of being and relating, and what we know or what we are *conscious* of without question is not some object or thing in which these relations inhere, but our act of relating as an opening style of being with the

world. Our style of being defies separation between the act of our sensing and the interconnected act of the panorama we experience, since both come together as one interaction. Every *objectively* discrete part of the panorama is an interaction, and in turn our experiencing of that panorama is an interaction with it.

We might think of energy as an infinitely diverse given totality of reality of interactions with which we interact and are a part by this very act of measuring out. "The variety of natural phenomena is thus created by the diversity of manifestations of energy."[69] Cassirer goes on to claim that the concept of energy is an abstraction in terms of numerical quantities which are far removed from the act of experience, but in maintaining this he is attempting to validate an ontology in terms of a reality which must point to a substantiality which causes our perceptions.[70] He loses sight of the possibility that the mathematical, numerical description is itself a style of interacting, and that this so-called abstract description is alien to our experience only if it cannot explain its own formulation. If mathematical ratiocination is shown to be part of a style of interacting having as much reality as the world because as a style of interacting it shares with the world its interacting nature, then relegating the mathematical to the abstract may be unwarranted. What makes a form of energy a form of energy is its style of interacting. What we study in physics is the quantified and qualified measurement of observational events for assuming distinctive styles of interacting, and furthermore, these *measurings* are a style of acting, a style of taking-up the world's act as part of our act, and thus we explain our numerical quantifying and qualifying of the energetic totality in terms of energetic

interaction itself, by explaining that it is the way we interact. I do not merely passively perceive the world, but rather, part of my interacting with the world is my measuring it, and this I do by *measuring* off sometimes discrete, sometimes ambiguous qualities and quantities of the total act of reality.

The most important point is that matter cannot explain to us our experience in general, it does not cohere with our so-called subjective or mental being. Newtonian physics was deemed a reliable source of knowledge for hundreds of years because it seemed to form a coherent system of mathematical and experimentally derived laws. The experimental method was merely a way of organizing experience so that possible confused perceptions could be avoided, but nonetheless, it was held to be reliable only to the extent that it was a network of laws which could be seen to form a coherent whole. This criteria of knowledge in terms of explanatory power has recently become suspect at least in part because of the revolution in science brought about by quantum theory and relativity theory which invalidated the previously presumed coherence of Newtonian physics. The reasoning which has served to place this kind of coherence in a dubious light is that since Newtonian physics was wrong, yet obviously coherent, then any claims to coherence of a scientific system are also possibly just misplaced faith. Crucial to the strong realist non-materialist ontology herein proposed is the claim that Newtonian physics was never a coherent system because the very framework of that system was inconsistent. The materialist ontology upon which Newtonian physics was based has always presented insurmountable problems because it could make no room for the

explanation of ratiocination itself. Given this scientific framework from which the beliefs about knowledge and perception were based, it was impossible to derive an explanation of how or why experience should be credible to begin with. Nothing within the Newtonian materialist physics could account for the perception of experience, and there is nothing within this system capable of explaining the very endeavors of organization, theoretical hypothesizing, and mathematical formulation which are essential to the system. In plainer terms, nothing in Newtonian materialism could account for human thought, and since the system itself was a product of human thought, there was a blatant gap in its foundation and its principles. Newton himself did not address this problem, nor did most adherents to Newtonian physics, but they should have. Instead, these problems were relegated to the field of philosophy, where they still remain. Had this very basis of physics been questioned from within the discipline of physics itself, then some more coherent theory might have been sought.

Energy, and its correlate interactivity, however, does offer a unified world of experience, it removes from our reflection on experience the kind of *dehiscence* which matter and mind show to be irreconcilable, and it thus gives us a more coherent ontology in keeping with a strong scientific realism. Granted, energetics does compartmentalize experience, yet a strong criterion of truth does not hinge on the meaningfulness of such compartmentalizations, rather, these *atomizations* are verifiable or relevant only to a holistic context of interaction wherein each aspect must fit into an overall pattern of interactions. A new kind of coherent theory of knowledge might prove to be our final criterion, not because

coherence is just naturally what fulfills our sense of logical satisfaction, but because only such coherence can mirror the world we experience. The ontology of interactivity not only satisfies this criteria of coherence, it demands that this kind of coherence be our criteria because the ontology here proposed claims that the world is a coherent multiplicity of interactive styles of interacting. These forms *hold together* in their interactiveness, so that coherence as interactive reality becomes most meaningful, for the world is not a world of discrete, solid, glue-like *stuffness*, but its perceived *solidity* is indeed its coherence as form of act-as-interact. In this vein, the experimental method might reclaim much of what was once seen as the connection between knowledge, perception, and science. The world itself, our knowledge and perception of the world, our scientific experiments and our formulating scientific hypotheses are all styles of interacting, and they are all interactively connected.

Notes

1. Bas Van Fraassen, *The Scientific Image* (Oxford: Oxford University Press, 1980), 82.

2. John Horgan, "Quantum Philosophy," *Scientific American* 267 (July 1992): 96.

3. Throughout this paper reference is made to ordinary experience. *Ordinary experience* should not be confused with what is referred to as common sense experience if one presumes that common sense refers to what most people believe ordinary experience to be. Ordinary experience refers instead to the experience of the world which all humans share.

4. Werner Heisenberg, *Philosophical Problems of Nuclear Science* (London: Faber and Faber, 1952), 55-56.

5. Nick Herbert, *Quantum Reality* (Garden City, N.Y.: Anchor Press, 1985), 26.

6. ibid., 186.

7. Heisenberg, *Philosophical Problems of Nuclear Science*, 43.

8. Heisenberg, *Physics and Philosophy* (New York: Harper and Row, 1958) 179-80.

9. A. J. Ayer, *Language, Truth, and Logic*, (London: Gollancz, 1936), 33-45.

10. Heisenberg, *Philosophical Problems of Nuclear Science*, 47.

11. Arthur Fine "How to Count Frequencies; A Primer for Quantum Realists," *Synthese* 42 (1979): 151-52.

12. Heisenberg, *Philosophical Problems of Nuclear Science*, 48.

13. ibid., 47.

14. Heisenberg, *Physics and Philosophy*, 175.

15. For an example of an author who commits such oversight see Patrick Heelan, *Quantum Mechanics* (The Hague: Martinus, 1965), xiii-xiv.

16. Heisenberg, *Philosophical Problems of Nuclear Science*, 27.

17. ibid., 96-97.

18. ibid., 29-31; *Physics and Philosophy*, 63.

19. Heisenberg, *Philosophical Problems of Nuclear Science*, 103.

20. ibid., 102.

21. ibid., 72.

22. ibid., 73.

23. Heisenberg, *Physics and Philosophy*, 145.

24. ibid., 186.

25. Heisenberg, *Philosophical Problems of Nuclear Science*, 103.

26. Heisenberg, *Physics and Philosophy*, 71.

27. ibid., 62-63.

28. For discussion of Heraclitus see Heisenberg, *Physics and Philosophy*, 63. For discussion of Aristotle see Heisenberg, *Physics and Philosophy*, 160.

29. ibid., 147-60.

30. Heisenberg, *Philosophical Problems of Nuclear Science*, 103.

31. isaac Newton, *Optics* (New York: Dover, 1952 reprint of 4th edition of 1730), 400.

32. ibid., 397.

33. Albert Einstein and Leopold Infeld, *The Evolution of Physics* (New York: Simon and Schuster, 1938), 56.

34. Newton, loc. cit.

35. Gottfried Wilhelm Leibniz, *Philosophical Papers and Letters*, trans. Leroy E. Loemker (Dordrecht, Holland: D. Reidel, 1969), 506.

36. ibid., 503-04.

37. ibid., 435.

38. ibid., 445.

39. ibid., 650.

40. ibid., 454.

41. ibid., 441.

42. ibid., 271.

43. ibid., 435.

44. ibid., 433.

45. No one source discusses the work of all authors mentioned here. Refer to bibliographic entries for their various philosophies.

46. Alfred N. Whitehead, *Process and Reality* (New York: Cambridge University Press, 1929), 233.

47. Philipp Frank, *Philosophy of Science* (Englewood Cliffs, N.J.: Prentice-Hall, 1957), 233-38.

48. Max Jammer, *Concepts of Force* (Cambridge: Harvard University Press, 1957), 242-43.

49. For a discussion of GUTs and the concepts of *force* and *energy* see Carl Friedrich von Weizsacher, *The Unity of Nature*, trans. Francis Zucker (New York: Farrar, Straus, & Giroux, 1980), 151.

50. Heelan, 163-64.

51. ibid., 164-65.

52. Heisenberg, *Physics and Philosophy*, 54-55.

53. Heisenberg, *Philosophical Problems of Nuclear Science*, 70.

54. Heisenberg, *Physics and Philosophy*, 57.

55. Heisenberg, *Philosophical Problems of Nuclear Science*, 103.

56. Rene Descartes, "Reply to the Second Set of Objections Urged by Certain Men Against the Preceding Meditations" in *The Philosophical Works of Descartes* trans. Elizabeth S. Haldane and G. R. T. Ross, vol. 2 (New York: Cambridge University Press, 1970), 47.

57. Heisenberg, *Physics and Philosophy*, 160.

58. Erwin Schrodinger. *What is Life? and Other Scientific Essays* (Garden City, N.Y.: Doubleday, 1956) reprinted in *Mystery of Matter* ed. Louise B. Young, (New York: Oxford University Press, 1965), 123.

59. Weizsacher, 131.

60. Heisenberg, "The Nature of Elementary Particles," *Physics Today* 29, no. 3 (1976): 34-39.

61. Heisenberg, *Philosophical Problems of Nuclear Science*, 105.

62. Maurice Merleau-Ponty, *Phenomenology of Perception* (London: Routledge and Kegan Paul, 1962), viii.

63. ibid.

64. Ernst Cassirer, *Substance and Function* (Chicago: Open Court Publishing, 1923), 190.

65. Heisenberg, *Philosophical Problems of Nuclear Science*, 67-68.

66. Heisenberg, *Physical Principles of Quantum Theory* trans. Peter Heath (Chicago: University of Chicago Press, 1930); reprinted in *Physical Thought from the Presocratics to the Quantum Physicists*, ed. Shmuel Sambursky (New York: Pica Press, 1975), 517-18.

67. Cassirer, 188.

68. ibid., 189.

69. Heisenberg, *Philosophical Problems of Nuclear Science*, 103.

70. Cassirer, 190-91.

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